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Technology and Finance

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Abstract

The benefits from financial development are known to vary across industries. However, no systematic effort has been made to determine the technological characteristics that are shared by industries that tend to grow relatively faster in more financially developed countries. This paper explores a range of technological characteristics that might underpin differences across industries in the *need* or the *ability* to raise external funding. The main finding is that industries that grow faster in more financially developed countries tend to display greater *R&D intensity* or *investment lumpiness*, indicating that well-functioning financial markets direct resources towards industries that grow by performing R&D.

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Keywords: Technology, financial development, external finance dependence, industry growth, R&D intensity, investment lumpiness.

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Contents Page

Figure:

Tables:

"The banker… is essentially a phenomenon of development… he makes possible the carrying out of new combinations [of productive means], authorises people, in the name of society as it were, to form them."

Joseph A. Schumpeter, "The Theory of Economic Development" (1911)

"We have entirely lost the idea that any undertaking likely to pay, and seen to be likely, can perish for want of money; yet no idea was more familiar to our ancestors, or is more common now in most countries. A citizen of London in Queen Elizabeth's time could not have imagined our state of mind. He would have thought that it was of no use inventing railways (if he could have understood what a railway meant), for you would not have been able to collect the capital with which to make them."

Walter Bagehot, "Lombard Street: A Description of the Money Market" (1873)

I. Introduction

In a frictionless economy, financial development should not matter for economic growth. In reality, dealing with various frictions that arise between lenders and borrowers is costly and consequently, financial development (that lowers such costs) may be beneficial for growth.[1]

Any theory of finance and growth relies on specific assumptions about the reasons why producers may *need* to draw on external funds, and why they may be *unable* to do so. The search for systematic factors that might determine the *need* or *ability* to raise external funds in an imperfect environment has led many researchers to believe that such factors are likely to be industry specific and technological in nature.[2] However, no systematic effort has been made to identify what these factors might be. This paper contributes to the literature by: (i) investigating which technological characteristics might underlie cross-industry differences in the *need* or the *ability* to raise external funds; (ii) developing empirical measures of these characteristics; and (iii) identifying the technological characteristics that are shared by industries that grow relatively faster in more financially developed economies.

Economic theory highlights several channels through which technology might influence the producer's *ability* to access external finance – ranging from collateral constraints to informational frictions. For example, firms with a larger share of durable fixed assets may find it easier to raise external funds even in underdeveloped financial systems, because such assets are more likely to be eligible to serve as collateral – see Kiyotaki and Moore (1997) – and because of a greater need to rely on collateral in the absence of alternative mechanisms to overcome financial frictions. However, it has not been established which technological factors are *empirically* relevant. Another strand of literature, pioneered by Rajan and Zingales (1998, henceforth RZ), explores the impact of financial development on growth

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[1] See Levine (2005) for a recent survey of the literature on financial development and economic growth.

[2] Industry characteristics that have been assumed to be technologically determined, and have been looked at in connection with either the need or ability to raise funds, include cash flow shortfalls relative to investment; asset tangibility; R&D intensity; firm size; and asset fixity. See Rajan and Zingales (1998), Claessens and Laeven (2003), Carlin and Meyer (2003), Beck, Demirguc-Kunt, Laeven and Levine (2004) and Braun and Larraín (2005) respectively.

using the premise that industry variation in the *need* for external finance is due to differences in production technology – an assumption that remains conjectural.[3]

We begin by identifying cross-industry differences in production technologies – defined in terms of the intensities with which factors of production, such as labor, physical capital, human capital and R&D, are used in different industries, as well as the attributes of these factors, such as the tangibility, alienability (ease of transfer) and durability (lifespan of the asset). We review the mechanisms through which these technological characteristics might affect the firms' *need* or *ability* to raise external finance, develop empirical measures of these technological characteristics, and examine whether relationships among them are stable over time and consistent with theory. Then, we exploit cross-country variation in industry growth rates to determine which technological characteristics are shared by industries that grow relatively faster in more financially developed environments.

We find that R&D-intensive industries and industries characterized by greater investment lumpiness tend to be the main beneficiaries of financial development. Our cross-country industry growth regressions suggest that investment lumpiness plays an important role during the 1970s, while R&D intensity remains important throughout the 1970s, 80s and 90s. We also find that industry rankings based on these variables are stable over time, as well as over the firm lifecycle, and are positively correlated with the ranking based on RZ's *external finance dependence* (EFD) measure. Moreover, our finding regarding the role of R&D intensity is more robust than that of either investment lumpiness or EFD. Hence, our main conclusion is that financial development stimulates growth by relieving financing constraints on industries that grow by performing R&D.

Section II surveys the literature, outlining factors that distinguish technology in one industry from another. Section III describes the data, and Section IV examines the links among our technological measures. Section V analyzes whether industry growth rates are significantly influenced by the interaction between any of the technological measures and financial development. Section VI assesses the robustness of the results, and Section VII concludes.

II. Theories of Finance and Technology

This section discusses how technology might affect a producer's *need* or *ability* to raise external finance, and formulates some empirical predictions.

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[3] The only study (that we are aware of) that attempts to validate the RZ premise is by Furstenberg and Kalckreuth (2006), who find at best weak links between their own industry-level external finance dependence measure and some variables they regard as "technological".

A. Financial Development and the *Ability* to Raise Funds

We can think of financial development as the development of institutions that facilitate access to external funding. Modeling and measuring financial development is complicated by the multiplicity of possible frictions that can arise between lenders and borrowers, as well as the variety of mechanisms that might be used to deal with such frictions.[4] Here, we focus on the question of how the production technology used by firms in a given industry might affect their *ability* to raise external funds in different environments.

Suppose that for a given level of financial development F_c in a country $c, L\left(F_c,\bullet\right)$ is a limit on how much a median firm may be able to borrow. We can think of F_c as an index that reflects that quality of provisions in a country's legal and institutional framework that help lenders to overcome financial frictions, for example, by allowing them to: (i) seize and sell assets pledged by borrowers as collateral, in the event of default; (ii) reduce the ex-ante risk of default and hence the need to rely on collateral – through better ex-ante project screening, better monitoring or more effective disclosure[5].

Thus, all else equal, greater financial development should relax the borrowing constraint for a median firm in country c :[6]

$$\frac{\partial L\left(F_c,\bullet\right)}{\partial F_c} \geq 0.$$

However, the limit L might depend not only on a country's institutional framework, but also on the characteristics of the *production technology* used by a median firm. In all but completely frictionless environments, firms that use a relatively large fraction of easily "collateralizable" assets will have, on average, a greater *ability* to borrow.[7] The

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[4]A financial friction is any type of problem that financial contracts cannot handle at zero cost. Examples include indivisibility or non-tradability (inalienability) of assets, agency and information problems.

[5] See Stiglitz and Weiss (1981) and De la Fuente and Marin (1996) among others.

[6] We can abstract from any changes in the creditworthiness of a median firm associated with business cycle fluctuations by measuring all the relevant variables over sufficiently long time periods.

[7] In Kiyotaki and Moore (1997), fixed assets serve dual roles – as factors of production and collateral for loans. One can think of dimensions of financial development other than the ones mentioned here: for example, the extent to which the loan originator is able to re-sell his claim in a secondary market (as in Kiyotaki and Moore, 2002), or the extent to which future output (or the proceeds thereof) can be collateralized. Here, we focus on collateralizability of productive assets that can be more directly related to the standard parameters of production technology.

collateralizability of assets depends on their attributes, such as the degree of tangibility,[8] alienability (ease of transfer) and durability (lifespan of the asset). For example, fixed assets can typically be used as collateral for loans even in less developed financial systems, whereas intangible assets are not always accepted as collateral even in more advanced financial systems. Industries that use intangible assets might then be expected to benefit disproportionately from improvements in financial systems.

So, let A_i be an index that reflects the degree of tangibility, alienability and durability of productive assets used by a median firm in industry i. Now, the *ability* of a median firm in industry i to use its productive assets as collateral should depend both on A_i and on the level of financial development F_c, because greater financial development might expand the range of collateralizable assets or reduce the need for collateral (for example, by improving disclosure requirements). Thus, for a median firm in industry i and country c, the borrowing limit L is a function $L\left(F_c, A_i\right)$, such that:

$$\frac{\partial L\left(F_c, A_i\right)}{\partial A_i} \geq 0, \ \frac{\partial L\left(F_c, A_i\right)}{\partial F_c} \geq 0, \ \frac{\partial^2 L\left(F_c, A_i\right)}{\partial F_c \partial A_i} \leq 0 .$$

B. Financial Development and the *Need* to Raise Funds

Assuming that the *need* for external funding also varies across industries – say, depending on the production technology,[9] the external finance requirement of a median firm in industry i (denoted N_i) may be either above or below $L\left(F_c, A_i\right)$ – the limit on how much it might be able to borrow in the financial environment of country c. If $N_i > L\left(F_c, A_i\right)$, then a larger share of firms in a given industry will find themselves unable to raise the needed funds.

In an advanced financial environment, for most industries, N_i is likely to be below $L\left(F_c, A_i\right)$ and hence the actual use of external funding by a median firm in industry i should equal N_i.[10] This is consistent with the RZ idea that the industry-specific *need* for external

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[8] We use "tangibility" in a narrow sense, to refer to whether or not an asset is fixed (property, plant and equipment). See Myers and Rajan (1998).

[9] We abstract away from any variations in short-run investment opportunities by measuring all relevant quantities over sufficiently long periods of time.

[10] Of course, in a less financially developed country, for an industry i, such that $N_i > L\left(F_c, A_i\right)$, the actual use of external funding by a median firm in industry i reflects its ability to raise external financing.

funding – *external finance dependence (EFD)* – can be measured as the share of capital expenditures that is not financed by cash flow from operations of a median firm in industry i in a highly financially developed country such as the U.S.

Why would some industries be inherently more external finance-dependent than others? RZ suggest that cross-industry differences in EFD may be due to "technological" factors specific to each industry. In particular, these could include the initial project scale, the gestation period, the cash harvest period, and the requirement for continuing investment.[11] To put it more generally, firms that use a production technology characterized by significant mismatches in the magnitude or timing of inputs and outputs are more likely to experience shortfalls in cash revenues relative to cash outlays than firms in other industries. If so, it should be possible to establish a link between the *need* for external funding and specific parameters of the production technology, such as factor intensities and attributes.

C. Financial Development and Industry Growth

How might technological differences in need and ability affect cross-country differences in rates of industry growth? Consider a simple environment in which production uses two inputs, labor and capital. Capital is accumulated gradually, and is imperfectly transferable across industries.[12] We use the term "capital", keeping in mind that it could be interpreted as physical capital, human capital, or R&D capital.

In a standard growth model, a country (or an industry) that starts out with a capital stock below the level that corresponds to its long-run growth path converges to that long-run level over time through capital accumulation. Let $\overline{k_i}$ represent the long-run capital level of an industry i in a frictionless economic environment, and let $k_{i,c} \leq \overline{k_i}$ represent the initial level of capital in an industry i located in country c, with $d_{i,c} = \overline{k_i} - k_{i,c}$ defined as a distance from the initial country specific level $k_{i,c}$ to $\overline{k_i}$. The rate at which industry i located in country c converges to its long-run growth path – its rate of growth $g_{i,c}$ – would depend on $d_{i,c}$ and other factors discussed below, i.e., $g_{i,c} = G_i\left(d_{i,c}, \bullet\right)$ where:

[11] "Initial project scale" is required investment before a project generates revenue; "gestation period" is the time period from the first investment outlay until cash revenues start to flow; "harvest period" is the period during which cash revenues are generated; and "continuing investment" is investment maintained continuously across periods. For example, a project may require "continuing investment" during both gestation and harvest periods.

[12] The following discussion applies broadly the intuition of the cross-country convergence model of Aghion, Howitt and Mayer-Foulkes (2005) to a multi-industry context, allowing financial development to have different effects on different industries.

$$\frac{\partial G_i}{\partial d_{i,c}} > 0 \qquad (1)$$

As one might expect, industry growth rates are also likely to be affected by the ability of firms to raise the funds necessary to accumulate capital. In particular, any shortfall between desired funds and accessible funds $s_{i,c} = N_i - L(F_c, A_i)$ experienced by a median firm in industry i of country c would hinder convergence. As a result, institutional frictions may slow the rate of convergence, particularly in industries that find themselves more severely constrained in less developed financial environments. Thus, $g_{i,c} = G_i(d_{i,c}, s_{i,c})$ where:

$$\frac{\partial G_i}{\partial s_{i,c}} \leq 0, \; \frac{\partial^2 G_i}{\partial s_{i,c}^2} \leq 0 \qquad (2)$$

The second derivative reflects the presumption that any capital that *is* raised is allocated to its most productive use within the industry, so there are decreasing returns to reducing the shortfall $s_{i,c}$ – again, reflecting the concavity of the underlying production technology.

Given the definitions of $d_{i,c}$ and $s_{i,c}$, it can also be shown that financial underdevelopment disproportionately slows the rate of convergence in industries with higher external finance requirements N_i, i.e.,

$$\frac{\partial^2 g_{i,c}}{\partial N_i \partial F_c} > 0 \qquad (3)$$

The latter also implies that after controlling for industry and country effects, we would expect the interaction between financial development and N_i to have a positive impact on industry growth (suggesting that this framework is consistent with the RZ results).

Moreover, given our assumptions, convergence is disproportionately slowed by financial underdevelopment in industries with particularly low ability to raise funds, i.e., lower A_i :

$$\frac{\partial^2 g_{i,c}}{\partial A_i \partial F_c} < 0 \qquad (4)$$

Thus, controlling for industry and country effects, we would expect the interaction between financial development and the technologically determined ability (inability) to raise external funds to be negative (positive) for industry growth.

So, based on the framework outlined above, we would expect those industries that have greater *need* for external finance – but also lower *ability* to use their productive assets as collateral for loans – to grow faster in more financially developed economies.

D. Technology

What specific characteristics of the production technology might relate to the need and/or the ability to raise external funds? A common approach to identifying the properties of a production technology – by means of measures of input use – dates back at least to Cobb and Douglas (1928). We consider a number of *factor intensities* and *factor attributes*, and relate them either to the *need* for external finance (if they are likely to exacerbate the mismatch in cash flows) or to the *ability* to raise external funding (if they are likely to increase the collateral value of productive assets, or reduce the severity of informational frictions). The discussion below is summarized in Table 1.

Capital vs. Labor

Need*:* Capital-intensive industries may be more finance dependent than labor-intensive industries to the extent that a higher need for continuing investment implies greater need for external finance.

Ability: On the other hand, capital-intensive industries may be better *able* to raise funds in less developed financial systems where only durable fixed assets can serve as collateral.

Physical Capital: Fixity

Need: Fixed capital may be more easily acquired than intangible capital, with the latter requiring time and firm-specific investments to generate (e.g., through R&D or advertising). Fixed capital may thus require lower startup costs or shorter gestation lags.

Ability: Fixed assets serve well as collateral due to their ease of detection, transferability and difficulty of diversion (in contrast, intangible assets are often inalienable: e.g., brand name recognition is inherently difficult to transfer).[13] Thus, industries that use more fixed assets may be better *able* to raise external finance in less developed financial systems.

Physical Capital: Durability

Need: The durability of capital determines how often it should be replaced. If the capital used by industry i depreciates faster than the capital used in industry j – e.g., if i uses relatively more equipment (as opposed to structures) than does j – then the cash harvest period in i may be shorter, or the requirement for continuing investment may be higher. This implies that industries that experience higher rates of capital depreciation are likely to be relatively more dependent on external finance.

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[13] See Myers and Rajan (1998).

Ability: More durable physical assets are more easily collateralizable. Thus, industries that use capital with higher rates of depreciation should have lower *ability* to raise external finance in less developed financial systems.[14]

Physical capital: Lumpiness

Need: Firm-level investment tends to occur in "spikes", often associated with large, non-convex adjustment costs.[15] Greater "lumpiness" of investment should exacerbate the mismatch between the firms' cash inflows and outflows and may compel the firm to seek external funding. Hence, industries with more frequent investment spikes are likely to be relatively more dependent on external funding.

Ability: Lumpy investment may also indicate that some of the firms' assets cannot be transferred (alienated) without being destroyed[16], and hence, are less suitable to serve as collateral.

Research & Development (R&D)

Need: R&D activity can lead to either product or process innovations (i.e., increases in the efficiency with which other inputs are used in production). One might expect more R&D-intensive industries to be relatively more dependent on external finance for several reasons. R&D does not yield immediate results, and thus may be associated with longer gestation periods. R&D may require large startup investments for new firms and also for new projects – in which case it may also be associated with investment lumpiness. R&D investments are also inherently risky and likely to be sunk.[17] In R&D intensive industries, a firm's market

[14] See Hart and Moore (1994). Greenwood et al (1997) and others relate a large slice of depreciation to *obsolescence* (rather than physical wear) due to technical change affecting capital goods, or *embodied technical change* (ETC). It is of interest to distinguish between the effects of physical depreciation and technological obsolescence, as obsolescence (the replacement of functional capital) is an economic decision that may be affected by credit constraints at the firm level (i.e., a firm may choose to delay the replacement of an obsolete, but functional machine).

[15] For example, Doms and Dunne (1998). The magnitude of nonconvex costs could be related to asset specialization which, in Hart and Moore (1994), is related to the ability to raise funds.

[16] In a study of the aerospace industry, Ramey and Shapiro (2001) present evidence that equipment cannot be moved between firms without losing some of its value (about ½ on average). In Sakellaris (2004) and Samaniego (2008), investment lumpiness is linked to the destruction of knowledge pertaining to the capital that is being replaced (i.e., capital itself need not be destroyed in the adjustment process).

[17] Burley and Stevens (1997), for example, suggest that the ratio of ideas produced in research departments to commercialized products is on the order of 1:1000.

niche may be constantly under threat from innovative competitors, so that expected harvest periods may be relatively short.[18]

Ability: R&D is an intangible asset, which is difficult to collateralize. Success in R&D is highly uncertain, and an R&D-intensive project may be difficult to monitor and assess, exacerbating agency problems. Thus, R&D intensive industries may have a low ability to raise finance in less developed financial systems, where monitoring costs are high.

Human Capital

Need: Human-capital intensive industries may require up-front investment to assemble an appropriately-skilled workforce. Moreover, if financial or labor markets are such that *individuals* find it difficult to finance investments in human capital, or if human capital has an important firm-specific component, then firms may choose to finance such investments themselves. This would raise their initial need for external funds – particularly since these are likely to be long-term investments that take time to pay off.

Ability: Human capital is inalienable and generally cannot serve as collateral, so human-capital intensive industries may find it hard to raise funds in less financially developed countries. In fact, selling claims against one's human capital is not very common even in fairly advanced financial systems.[19]

To recap, our conjecture (formulated at the end of the previous section) is that industries that have both a high *need* for external finance and a low *ability* to raise it are likely to be the main beneficiaries of financial development. Now, this conjecture can be recast in terms of the technological characteristics discussed above, i.e., industries with greater *investment lumpiness*, higher rates of *capital depreciation* or *obsolescence*, lower share of *fixed* assets, higher *R&D intensity* and higher *human capital intensity* are likely to benefit from financial development. Industries with higher *R&D intensity* and *investment lumpiness* may be at a particular disadvantage in less financially developed economies given their high share of irreversible investments of a firm- or project-specific nature, which imply large or frequent expenditures on assets that are inalienable from the firm.

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[18] See the survey by Kamien and Schwartz (1982). While one might be concerned that firms in R&D intensive industries do not perform R&D in developing countries, Cohen and Levinthal (1990) show that R&D is required not just to develop innovations but also to absorb innovations made outside the firm.

[19] See Hart and Moore (1994). There are exceptions. For instance, in January 1997, David Bowie raised $55 million by issuing ten-year bonds backed by the future royalties from his albums recorded before 1990. Similar deals have been signed by several American songwriters, and by the band Iron Maiden.

Table 1. Production Technology: *Need* for External Finance vs. *Ability* to Raise External Funds.

Technological measure (X_i)	Defined as	How does X_i affect the *ability* to access external finance (A_i)?	How does X_i affect the *need* for external finance (N_i)?
CAPITAL			
Fixed capital (FIX)	- a fraction of total assets	↑ - higher tangibility	↓ - lower startup costs, shorter gestation.
Depreciation (DEP)	- a fraction of capital stock	↓ - lower durability	↑ - greater need for follow-up investment
Obsolescence (ETC)	- the rate of decline in the quality-adjusted price of capital	↓ - lower durability	↑ - greater need for follow-up investment
R&D (RND)	- R&D spending as a fraction of capital expenditures	↓ - lower alienability, lower tangibility	↑ - longer gestation period, high startup costs, shorter harvest periods
Investment lumpiness (LMP)	- average number of investment spikes.	↓ - lower alienability	↑ - higher adjustment costs
LABOR			
Labor intensity (LAB)	- a fraction of value added	↓ - lower alienability, lower tangibility	↓ - lower need for follow-up investment
Human capital (HC)	- average wage	↓ - lower alienability, lower tangibility	↑ - longer gestation period, shorter harvest periods

See Section III for a detailed description of the construction of technological variables and data sources.

III. DATA

This section describes the construction of (A) industry-level measures of external finance dependence (based on US data); (B) industry-level technological measures (based on US data); and (C) country measures of financial development.

A. Finance Dependence

We adopt the RZ definition of external financial dependence (EFD): the share of capital expenditures that is not financed by cash flow from operations. Capital expenditures correspond to DATA 128 in Compustat. Cash flow from operations is defined as cash flow from operations plus changes in payables minus changes in receivables plus changes in inventories, and is computed using DATA 110 and DATA 2, 3 and 70, or DATA 302, 303 and 304 if unavailable. Both capital expenditures and cash flow are summed up over the relevant decade (the 1970s, the 1980s or the 1990s) to compute the firm-level EFD measures. The industry-level measure is the EFD of the median firm.

B. Technological Measures

Technological measures are constructed for 28 manufacturing industries using U.S. data. The time period under consideration is 1970-1999, which allows us to examine whether the behavior of these technological measures (as well as EFD) is stable over sufficiently long period of time (in contrast, RZ focus on the 1980s).[20] Our industry classification is coarser than that used by RZ, but has the advantage that it also covers the 1990s. Following RZ's procedure for constructing the EFD measure, firm-level measures are computed over each decade and industry-level measures are taken to be the median firm values (unless described otherwise, see below). The data comes from several sources: the INDSTAT3 database from the United Nations Industrial Development Organization (UNIDO), the Standard and Poor's Compustat database of publicly traded US firms, the US Bureau of Economic Analysis (BEA) capital flow tables, and from Cummins and Violante (2002). Industry growth data come from INDSTAT3.

Technological measures (reported in Table 2A)[21] are constructed as follows:

- *Fixity of assets* (FIX) is measured as the ratio of fixed assets to total assets (DATA 8 divided by DATA 6 in Compustat), as in Braun and Larraín (2005).

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[20] UNIDO replaced the dataset used by RZ with INDSTAT3 in 1993. INDSTAT4 is more disaggregated, but coverage is less complete and most technological measures could not be developed for such a fine partition.

[21] See Appendix.

- *R&D intensity* (RND) is defined as R&D expenditures divided by capital expenditures (DATA 46 divided by DATA 128 in Compustat).

- *Depreciation* (DEP) is the industry rate of capital depreciation, computed from the BEA capital flow tables and averaged over the decade in question (see Table 2A).

- *Obsolescence* or Embodied technical change (ETC): We measure ETC using the methodology and data of Cummins and Violante (2002), whereby a long-term decline in the (quality adjusted) price of the capital goods used by industry *i* relative to industry *j* reflects a faster rate of technical progress in the production of the capital goods used by *i* as compared to *j* (see Table 2A).

- *Labor intensity* (LAB) is defined as total wages and salaries divided by valued added, as reported by UNIDO.[22]

- *Human capital intensity* (HC) is defined as total wages and salaries divided by total employees, as reported by UNIDO. This follows Mulligan and Sala-i-Martin (1997).

- *Investment lumpiness* (LMP) is the average number of investment spikes experienced by firms in a given industry over a period of time. Following Doms and Dunne (1998), a *spike* is an annual capital expenditure in excess of 30% of the firm's stock of fixed assets.

C. Financial Development Measures

We use the same sample of 41 countries as RZ (Table 2B)[23] and construct the following measures of financial development:

- the *domestic private credit-to-GDP* ratio (CRE). Domestic credit data come from the IMF International Financial Statistics (IFS) (domestic credit allocated to the private sector is IFS line 32d).[24]

- the *domestic capitalization-to-GDP* ratio (CAP), the sum of domestic market capitalization and private credit. Market capitalization is based on the World Stock Exchange Factbook of the International Finance Corporation (IFC).

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[22] We do not use Compustat to measure LAB and HC because of data incompleteness. For example, in the 1980s none of the firms in ISIC 323 (Leather) reported DATA42, Labor and Related Expenses, to Compustat.

[23] See Appendix.

[24] GDP is measured in constant prices multiplied by the PPI (or by CPI, if PPI is not available), where the base year is five years before the year of interest (see RZ for more details).

- the ratio of *foreign and domestic liabilities-to-GDP* (FOR), the sum of domestic market capitalization and foreign liabilities of the private domestic non-financial sector (based on the BIS data).

CRE and CAP are standard measures of financial development, used in the finance and growth literature since at least King and Levine (1993). Although CAP is broader than CRE, it may not always accurately reflect the amount of funds raised in domestic financial markets for productive activities (due to tax incentives to list on stock exchanges, stock market dynamics being driven by factors other than fundamentals, etc). Hence, in what follows we use CRE as our benchmark. FOR is an even broader measure than CAP, as it also captures direct access of domestic non-financial sector entities to foreign sources of funding (this measure has not been considered by RZ).[25]

For each country, we average each financial development measure over the decade of interest in order to reduce the effects of short-term fluctuations in economic or financial market conditions.[26] A potential concern with using the average levels of financial development measured over the same period as the industry growth rates is endogeneity, whereby economic growth that emerges for reasons outside the model might affect the level of financial development. This, however, is unlikely to be a serious problem as growth data are at the industry level whereas financial development is measured at the country level. Nonetheless, we check the robustness of our results using instrumental variables.

IV. Empirical Relationships between Technological Measures and EFD

In order to convince ourselves that the technological measures described above do indeed capture certain time-invariant industry-specific characteristics, we examine the empirical relationships between industry rankings based on these measures both across time and across measures. Consistent with our interpretation, we find that industry rankings based on all technological measures are highly *auto-correlated* (Table 3). Moreover, these rankings also appear to be *stable across countries*. Each of the LMP, RND and FIX measures computed

[25] RZ, however, also use an index of accounting standards, which is available for the 1980s, but not for other periods, as yet another proxy of financial development. We obtain similar results for the 1980s using this index. Correlations between different measures of financial development within decades, or the same measure across decades, are 85% or higher in all cases.

[26] In contrast, RZ measure CAP and CRE at the end of the first year in the 1980s for which they have data. We found our ability to replicate RZ's results to be sensitive to our choice of initial year. Market capitalization can indeed change dramatically within a year. For example, Austrian stock market capitalization doubled permanently in 1985: see http://en.wienerborse.at/static/cms/sites/wbag/media/en/pdf/about/history.pdf . In the 1980s, the correlations between the RZ's values of CRE and CAP and ours are over 80 percent when computed for the same industry breakdown.

using Compustat Global data for the 1990s is highly correlated (over 90%) with the same measure computed using the US data. Excluding US-incorporated firms from Compustat Global, the correlations with US measures for the available industries remain high, at 98% for RND, 67% for LMP and 85% for FIX. In the case of LAB and HC, we compared the US values for these measures with values computed using UNIDO data on India for the 1980s, finding correlations of 40% for LAB (significant at the 5% level) and 78% for HC. It was not possible to repeat this comparison for DEP and ETC, because of the lack of comparable data for other countries.

Relationships among *industry rankings based on different technological measures* are mostly stable over time (Table 4), and generally consistent with theory. In particular,

- Consistent with the theory of *capital-skill complementarity*[27], we find a negative relationship between HC and LAB. Interestingly, HC is positively correlated with FIX, suggesting that human capital is primarily complementary to *fixed* capital. Consistent with the presumption that human capital is required for R&D activity, the correlation between RND and HC is positive in all decades, although not statistically significant.[28]

- Consistent with evidence that relates *investment spikes* to the *construction and destruction of organization specific knowledge*[29], we find that investment is lumpier in industries with a larger proportion of intangible assets (low FIX). We also find that these industries tend to be relatively more R&D-intensive. This suggests that the knowledge developed through R&D is to some extent tied to the product line or production process it engenders, making capital adjustment costly. The correlation between DEP and LAB is positive in all decades, consistent with some parameterizations of the putty-clay model.[30]

- The diffusion of information technology (IT) is widely believed to have *increased flexibility at the plant level* (e.g., via computer aided-design, or the ability to switch between product lines)[31]. If so, industries with inherently lumpy investment might be more likely to adopt IT which, in turn would increase their ETC ranking – since IT is the

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[27] See, for example, Krusell et al (2000).

[28] Closer examination reveals that significance depends on an outlier. The most HC intensive industry is ISIC 353 (Petroleum refining), which has relatively low R&D intensity. Excluding ISIC 353, the correlation between HC and RND is positive in each decade with a P-value between 5% and 8%.

[29] See, for example, Sakellaris (2004).

[30] See Adachi (1974)

[31] See, for example, Milgrom and Roberts (1990).

type of capital good with the highest rate of ETC.[32] Consistent with this, we find that the link between LMP and ETC becomes positive and statistically significant in the 1980s and 1990s, the decades of the greatest IT diffusion. On the other hand, the link between LMP and DEP (physical depreciation) is positive and significant in the 1970s and 1980s, but disappears in the 1990s, suggesting that investment spikes increasingly tend to occur because of obsolescence rather than physical depreciation.

What is the relationship between these technological measures and EFD? Out of all the technological measures considered in this paper, only two – *lumpiness* and *R&D intensity* – are clearly related to EFD (Table 5). The correlations between industry rankings based on LMP and on EFD are positive and statistically significant in all three decades, consistent with the idea that investment lumpiness may be related to a greater need for external finance (as it exacerbates the mismatch between cash flows) or a weaker ability to raise finance (because it may be associated with poor alienability of assets). The correlations between industry rankings based on RND and on EFD are very high for the 1980s and the 1990s – over 80% – but not statistically significant in the 1970s. The relatively weaker relationship between EFD and both LMP and RND in the 1970s suggests that the U.S.-based measure of EFD may have been less driven by stable technological factors in the 1970s than in other decades (e.g., due to the energy price shocks and imposition of price controls in the U.S. in the mid-1970s).[33]

V. TECHNOLOGY, FINANCIAL DEVELOPMENT AND INDUSTRY GROWTH

What technological characteristics are shared by industries that tend to grow relatively faster in countries with higher levels of financial development? Because the need and the ability to raise external funds may be driven by independent factors, the correlation between EFD and R&D intensity on its own does not imply that, for example, financial development necessarily relieves financial constraints on firms in R&D intensive industries. In the same vein, the *lack* of any statistically significant relationship between EFD and the other technological measures does not necessarily imply that financial development might not disproportionately affect, say, human capital-intensive industries, through other channels.

Hence, we proceed as follows. For each technological measure X_k, we run a cross-country industry growth regression with the interaction variable for X_k and financial development. The estimated panel regression equation is

[32] See Cummins and Violante (2002). In the 1990s, FIX and ETC are positively correlated, which is consistent with the sharply increasing share of IT in overall physical investment during the period.

[33] Nonetheless, we do find that EFD and RND are significantly related at the *firm* level in each decade including the 1970s, even when industry dummy variables are introduced. Results are available upon request.

$$g_{i,c} = \alpha_i + \beta_c + \gamma \times SHARE_{i,c} + \delta X_{ki} \times FD_c + \varepsilon_{i,c} \tag{5}$$

where $g_{i,c}$ is growth in real value added in industry i and country c, α_i is an industry fixed-effect, β_c is a country fixed-effect, $SHARE_{i,c}$ is the share of industry i in the manufacturing sector of country c, X_{ik} is the value of technological measure k in industry i and FD_c is a measure of financial development in country c.[34] The objective is to determine whether the interaction between any of the technological measures and financial development may be a significant factor of industry growth differences (in what follows, we use the circumflex $\widehat{X_k}$ to refer to the interaction term between a technological variable X_k and a particular measure of financial development). We also run (5) with EFD in place of X_k, to verify that the RZ results hold in our data and to compare the behavior of our technological measures with that of EFD.

Focusing on the ***1980s*** and using ***CRE*** as a measure of financial development, we obtain the following results (Table 6):

- The results of RZ hold for our coarser industry classification: the interaction term of EFD with financial development ($\widehat{\text{EFD}}$) carries a positive and significant coefficient.

- The technological variables that interact significantly with financial development in the 1980s are RND, LMP, DEP and HC. Of note is that the coefficients on $\widehat{\text{RND}}$ and $\widehat{\text{LMP}}$ are positive, with a higher level of significance than that of $\widehat{\text{EFD}}$. In addition, some technological variables that (unlike RND) are not correlated with EFD also interact with financial development, consistent with the idea that financial need and ability may not be linked to the same technological factors. In particular, the sign of the coefficient on $\widehat{\text{DEP}}$ is positive, which means that industries that used less-durable capital tended to benefit more from financial development in the 1980s.[35] The coefficient on $\widehat{\text{HC}}$ is also positive.

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[34] As in RZ, the initial industry share controls for initial conditions. Its omission does not notably affect results.

[35] This ties in with Hart and Moore (1994), and may explain Furstenberg and Von Kalckreuth's (2006) finding of a negative link between their measure of EFD (computed based on the sample of all firms, not only publicly traded firms) and DEP in their data, which they consider puzzling. Since their data include firms that may be credit constrained, firms that have assets that are hard to collateralize may be less able to raise external finance and may thus appear to have low EFD. If the median firm in Compustat is financially unconstrained, and asset durability is related to the *ability* but not the *need* to raise external finance, we might expect to see a significant interaction of DEP with financial development in spite of a weak relationship between EFD and DEP – which is what we find.

How should one interpret the coefficients on the interaction terms $\widehat{X_k}$? Since fixed effects account for much of the variation in the data, the R^2 values alone do not give much indication of the economic significance of the interaction variables. The following example, however, might give a sense of economic significance of the interaction term. The country at the 75th percentile of financial development is France, and that at the 25th percentile is Egypt. The industry at the 75th percentile of EFD is Furniture, and the industry at the 25th percentile is Textiles. This means that if financial development in an average country were to improve from the level of Egypt to the level of France, Furniture would grow 0.9% faster annually than Textiles. Similarly, the industry at the 75th percentile of RND is Industrial Chemicals, and Food Products is at the 25th percentile of RND. If financial development in an average country were to improve from the level of Egypt to the level of France, Industrial Chemicals would grow 1.1% faster annually than Food Products. Note that this represents the differential (not the absolute) effect of financial development on industry growth. The average growth rate across industries and countries is 0.57% and the standard deviation is 0.65%, so these coefficients are large.

In the single-variable regressions (Table 7), $\widehat{\text{RND}}$ and $\widehat{\text{LMP}}$ carry larger coefficients and greater statistical significance than $\widehat{\text{EFD}}$. At the same time, this could simply represent omitted variable bias, as the three variables RND, LMP and EFD are correlated amongst themselves. Another way to see which of these interactions is strongest is to include all three variables in the same cross-country, cross-industry regression – a "***horse race***". Table 9 presents the results of the panel regression with industry shares, industry and country fixed effects, and all three interaction terms: $\widehat{\text{EFD}}$, $\widehat{\text{RND}}$ and $\widehat{\text{LMP}}$. We find that $\widehat{\text{EFD}}$ and $\widehat{\text{LMP}}$ lose statistical significance, whereas $\widehat{\text{RND}}$ does not.

VI. PERSISTENCE AND ROBUSTNESS

The robustness of the results is checked with respect to (A) different time periods; (B) other measures of financial development; (C) potential endogeneity of financial development; (D) the effect of firm age.

A. 1970s and 1990s

Can results similar to those for the 1980's be obtained for other time periods, i.e., for the 1970s or for the 1990s?[36] In each of these decades, industry growth patterns, as well as patterns of financial development, may have been affected by both secular and transitory factors which may be difficult to disentangle. During the 1970s, industry growth was

[36] As a matter of robustness, RZ do in fact check whether EFD as measured during the 1970s is related to industry growth during the 1980s, although they do not check whether EFD as measured in the 1970s is related to industry growth during the 1970s.

impacted by oil shocks and new environmental regulations.[37] Also, in the 1970s, financial market restrictions were more widespread than in later periods, even in the United States, so that even large publicly traded U.S. firms may have been subject to some financial constraints. The 1990s were the decade of the high-tech boom and increased flexibility of production processes in many areas of manufacturing due to the adoption of new technologies (as discussed above). The 1990s were also characterized by rapid financial liberalization.

Focusing on the ***1970s*** and using ***CRE*** as a measure of financial development (Table 6), we find that $\widehat{\text{EFD}}$, $\widehat{\text{RND}}$ and $\widehat{\text{LMP}}$ carry significant, positive coefficients, as in the 1980s. However, $\widehat{\text{FIX}}$ is statistically significant as well (unlike in the 1980s). The coefficient on $\widehat{\text{FIX}}$ is negative, which means that industries that use relatively larger share of *intangible* assets tended to benefit disproportionately from financial development in the 1970s. Focusing on the ***1990s*** and using ***CRE*** as a measure of financial development (Table 6), we find that $\widehat{\text{EFD}}$ and $\widehat{\text{LMP}}$ are no longer statistically significant, while $\widehat{\text{RND}}$ remains statistically significant.

To sum up, we find that:

- $\widehat{\text{RND}}$ is the only variable that remains statistically significant in all three decades;
- the interactions of LMP and of EFD with financial development are similar across decades, but the $\widehat{\text{LMP}}$ coefficients are larger in magnitude and significance;
- certain other technological interaction variables appear significant in the 1970s or in the 1980s, but none of them persist across decades.[38]

How should one interpret these results? ***First***, the results show that the interactions of RND and LMP with financial development are robust. In particular, while the "horse race" in the 1970s has no clear winner, R&D stands out in both the 1980s and 1990s. ***Second***, cross-industry differences in technology that appear unrelated to the *need* to raise external finance

[37] See, Gray (1987)

[38] Perhaps, some of these variables may not matter because they relate to inputs that are easily substitutable in the face of institutionally determined costs. We tested this for the case of LAB and HC, for which we have data for all 41 countries as these measures are drawn from UNIDO. We estimated equation (5) replacing industry growth g_{ij} with LAB_{ij} or HC_{ij} as the case may be. We did not find significant interaction coefficients, suggesting that financial underdevelopment does not systematically encourage firms to substitute capital for labor or high-skilled for low-skilled labor. This could reflect either low substitutability, or else large differences in input substitutability across industries, a hypothesis that could be checked in future work using firm-level data.

seem to matter as well. However, these results do not persist across decades.[39] ***Third***, the results confirm that EFD can indeed be viewed as a proxy for some technological industry characteristics, with LMP and RND being the leading candidates – nonetheless, the horse-races suggest that EFD may not be capturing the full range of interaction between finance and technology.

B. Other Measures of Financial Development

Are the results robust to different measures of financial development? Table 8 presents the findings of the same exercise performed for the 1980s, but with CAP as a measure of financial development. The results are essentially the same.[40] Using FOR as a measure of financial development also yields broadly similar results as those with CRE and CAP: R&D intensity interacts with financial development during the 1980s and 1990s, whereas EFD, DEP and LMP only interact during the 1980s (Table 9).

C. Endogeneity of Financial Development

Is there a risk that we may be capturing feedback effects between growth and financial development? Because we focus on the impact of financial development on differences in growth rates across industries (not on aggregate growth), endogeneity is unlikely to be a problem. Nonetheless, we use several approaches to address this concern.

First, we run cross-country industry growth regressions for the 1980s using financial development measured in the 1970s (Table 10). The coefficients on $\widehat{\text{RND}}$ and $\widehat{\text{LMP}}$ remain robust but, interestingly, the coefficient on $\widehat{\text{EFD}}$ does not.

Second, we examine whether the significance of $\widehat{\text{EFD}}$ (and of $\widehat{\text{RND}}$) in the 1980s is robust to instrumenting financial development with the country's *legal origin*, following La Porta et al (1996). We use the standard two-stage procedure, where in the first stage, we regress all exogenous variables (including the instruments) on $\widehat{\text{EFD}}$ (or on $\widehat{\text{RND}}$, $\widehat{\text{LMP}}$), and then use the predicted values $\widehat{\widehat{\text{EFD}}}$ (or $\widehat{\widehat{\text{RND}}}$, $\widehat{\widehat{\text{LMP}}}$) from the first stage to estimate regression equation specification (5) in the second stage (Table 11).[41] We find, as do RZ, that

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[39] This suggests they may reflect the impact of certain kinds of shocks – such as the oil price shocks – which might be better weathered by firms with a greater ability to raise external funds.

[40] We also used CAP minus CRE as a financial development indicator, to see whether debt and equity and hence financial structure have differential effects. We obtained essentially the same results as in Table 8.

[41] The first stage requires using the interactions of legal origin with industry measures as instruments to predict the interaction term. Using the instruments to predict values of financial development, and then interacting the

(continued)

instrumenting financial development in this way increases the coefficients on the EFD interaction term. Moreover, the same is true of the interaction term between R&D and financial development, as well as LMP and financial development. Thus, our findings regarding LMP and RND are robust as well. Finally, we use CRE measured in the 1970s to instrument CRE in the 1980s: results are similar.

D. Does Firm Age Matter?

There is a widespread presumption that external finance is more important for young firms than for established firms. In what follows, we explore whether the significance of $\widehat{\text{EFD}}$, $\widehat{\text{RND}}$ or $\widehat{\text{LMP}}$ is affected by the age of the firms used to compute these measures. To do this, we split the 1980s sample of firms into "young" firms, i.e., those that have been listed for fewer than ten years, and "mature" firms, i.e., those that have been listed for more than ten years. We then compute measures of EFD, RND and LMP using only young or only mature firms.[42]

We find that industry rankings based on RND and LMP are stable over the firm life cycle, whereas the ranking by EFD is not. In particular, in the 1980s, the correlation between EFD among the young and EFD among the mature is just 13%. By contrast, the correlation between RND measured for the two age groups is high, regardless of the decade (Table 12). The same is true of LMP. The correlation between EFD and RND is not stable across time and age groups, whereas the correlation between RND and LMP is the same regardless of the age group.

The cross-country industry growth regressions with measures of EFD, LMP and RND computed using different age groups (Table 13) show that:

- $\widehat{\text{EFD}}$ is significant only in the 1970s, and only among the mature. RZ find the same result for the 1980s.

- $\widehat{\text{RND}}$ remains significant regardless of firm age or the measure of financial development. The same is true of $\widehat{\text{LMP}}$. Indeed, in many cases the interactions are stronger for the age-specific measures than for the measures computed using firms from both age groups.

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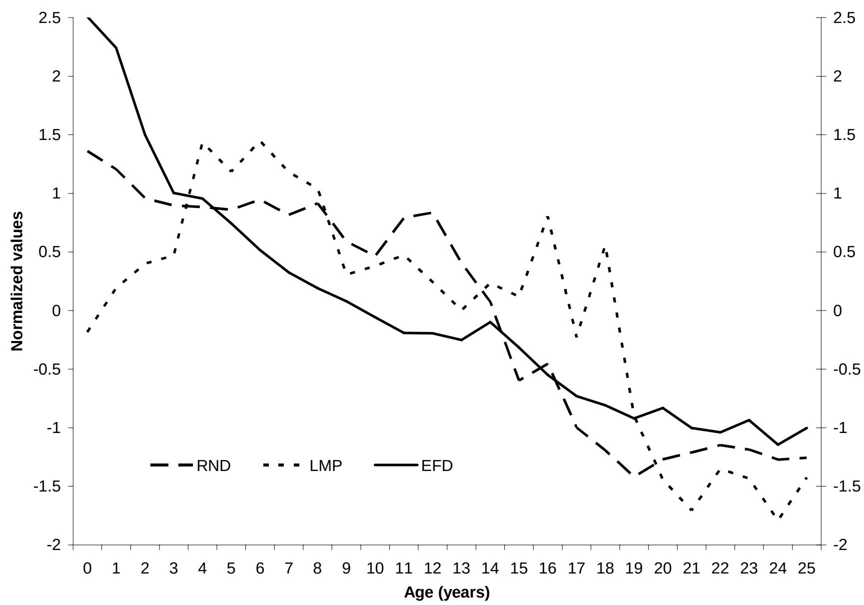
predicted values of financial development with the industry variables in the second stage, does not yield a consistent estimator. See Wooldridge (2002) p236 for a related discussion.

[42] We measure age using the date when Compustat starts reporting accounts receivable or capital expenditures. Compustat does not report IPO dates.

It is worth noting that these results are not driven by the fact that EFD changes over the firm lifecycle, whereas LMP and RND do not. Figure 1 plots EFD, RND and LMP computed for firms of different ages over the 1980s, showing that all three measures change along the firm's lifecycle. More specifically, there is a clear downward trend in RND and EFD; LMP also displays a downward trend, except for a rise in the first 5 years or so.[43] Thus, it is not the case that LMP and RND do not change over the firm's lifecycle: rather, *industry rankings* based on LMP and RND are stable over the firm lifecycle, whereas the EFD-based ranking is less so.

Figure 1: EFD, LMP and RND over the Firm Lifecycle.



External finance dependence (EFD), investment lumpiness (LMP) and R&D intensity (RND) by age, in years. Values are normalized by the standard deviation and mean of each variable.

Thus, unlike EFD, R&D intensity and investment lumpiness interact with financial development regardless of the age of the firms used to compute these measures. This is consistent with the hypothesis that R&D intensity and investment lumpiness are stable industry characteristics that interact with financial development to generate differences in industry growth rates.

[43] The initial rise suggests that lumpy investment represents the introduction of a new technology or the abandonment of an old one, as in Samaniego (2008), which is unlikely to occur early in a firm's life.

VII. Concluding Remarks

After reviewing a range of technological factors that might underlie cross-industry differences in the *need* or the *ability* to raise external finance, we conjecture that industries that have greater *need* for external finance, but also lower *ability* to use their productive assets as collateral, are likely to be the main beneficiaries of financial development. Indeed, we find that industries characterized by greater investment lumpiness and higher R&D intensity tend to grow faster in more financially developed countries.

We see several avenues for future work.

It would be interesting, though challenging, to assess the extent to which financial development encourages growth in R&D intensive industries via improvements in total factor productivity, factor-saving technical change, or factor accumulation. Tadesse (2005) takes a step in this direction, finding that financial development may encourage total factor productivity growth in industries in which young firms are financially dependent. Based on our findings, we would not be surprised to see that more R&D-intensive industries realize faster rates of technological progress in more financially developed countries.

Several theories link financial development to aggregate growth rates in general equilibrium models. However, to our knowledge, there are no general equilibrium models relating financial development to *industry* growth rates – in spite of the frequent use of industry growth rates in empirical work. Our results suggest that R&D intensity and possibly investment lumpiness may be important ingredients of such theories.

Finally, some policy issues should be mentioned as well. The subsidization of research activity is often recommended as a stimulus to growth, which seems to be consistent with R&D intensive industries having greater *need* for external finance, but also lower *ability* to raise the needed funds in less financially developed countries. Our results suggest that growth in R&D intensive industries can be promoted by encouraging financial development.

Appendix
Table 2A: Industry Classification and Technological Measures

EFD, LMP and RND are constructed using the Compustat database. Compustat reports a 4-digit SIC code for each firm, which can be easily aggregated to the 3-digit ISIC level. HC and LAB are constructed using UNIDO data. ETC and DEP are constructed using capital flow tables from the United States Bureau of Economic Analysis (BEA), which report investment expenditures, current cost stock and current cost depreciation in each industry by type of capital good.[44] The industry classification in the capital flow tables is slightly coarser than that used by UNIDO. For example, Food, Beverages and Tobacco constitute one category under the former system. To measure ETC differences among sub-industries, we proceed as follows. First, we construct ETC measures for the sub-industries using the 1987 benchmark input-output tables, which are more disaggregated than the capital flow tables. We then multiply them by a common factor so that their average equals the average for the full Food, Beverages and Tobacco category as computed from the BEA capital flow tables (We are grateful to Gianluca Violante for providing us with quality-adjusted capital goods price series.) As for DEP, the equipment share of investment in the capital flow tables (EQ) is highly correlated with DEP, suggesting that this share is the primary determinant of depreciation rate differences. We impute values of DEP for subcategories using relative differences in equipment and structures intensity, and the differences in the depreciation rates of equipment and structures across sub-industries reported by the BEA. In fact, in terms of correlations and industry growth regressions, we found that EQ and DEP behave very similarly. DEP and ETC are reported as percentages.

Industry	ISIC code	EFD	DEP	ETC	RND	HC	LAB	FIX	LMP
Food products	311	-0.090	7.110	3.487	0.061	0.162	0.271	0.379	1.326
Beverages	313	-0.234	7.110	3.511	0.014	0.217	0.245	0.353	1.333
Tobacco	314	-0.686	5.293	3.511	0.347	0.241	0.116	0.207	0.546
Textiles	321	0.092	7.568	3.623	0.111	0.131	0.457	0.328	1.451
Apparel	322	-0.055	6.288	4.053	0.000	0.096	0.444	0.127	1.459
Leather	323	-0.415	9.238	3.718	0.317	0.126	0.443	0.148	1.909
Footwear	324	-0.839	8.253	3.763	0.067	0.103	0.434	0.153	2.156
Wood products	331	0.218	9.588	3.797	0.000	0.146	0.491	0.296	1.650
Furniture, except metal	332	-0.098	8.125	3.938	0.165	0.133	0.485	0.289	1.266
Paper and products	341	-0.102	8.557	3.035	0.059	0.217	0.355	0.464	1.114
Printing and publishing	342	-0.178	9.636	4.084	0.000	0.177	0.394	0.282	1.984
Industrial chemicals	351	0.011	9.225	3.720	0.326	0.263	0.250	0.402	1.537
Other chemicals	352	1.670	6.628	3.792	1.369	0.221	0.214	0.207	2.366
Petroleum refineries	353	-0.115	6.649	3.623	0.048	0.309	0.177	0.590	0.569
Misc. pet. and coal products	354	-0.052	6.649	3.691	0.209	0.221	0.300	0.322	1.625
Rubber products	355	-0.034	9.826	3.038	0.317	0.197	0.426	0.294	0.821
Plastic products	356	0.048	9.826	3.097	0.188	0.158	0.405	0.368	1.727
Pottery, china, earthenware	361	-0.010	8.508	4.547	0.203	0.159	0.478	0.418	1.125
Glass and products	362	0.339	7.850	4.325	0.178	0.200	0.415	0.418	1.571
Other non-metallic mineral prod.	369	0.073	8.508	4.696	0.049	0.185	0.389	0.512	0.970
Iron and steel	371	-0.023	6.620	3.109	0.068	0.246	0.504	0.421	0.936
Non-ferrous metals	372	0.035	5.485	3.099	0.107	0.221	0.463	0.345	1.358
Fabricated metal products	381	-0.087	7.000	3.282	0.155	0.180	0.456	0.275	1.500
Machinery, except electrical	382	0.622	8.832	4.970	0.924	0.216	0.443	0.204	2.817
Machinery, electric	383	0.658	9.117	4.467	0.753	0.202	0.423	0.227	2.770
Transport equipment	384	0.038	10.790	4.237	0.398	0.256	0.454	0.268	1.716
Prof. & sci. equip.	385	1.090	9.110	4.137	1.176	0.217	0.382	0.185	2.961
Other manufactured prod.	390	0.431	9.967	2.782	0.353	0.144	0.404	0.179	1.986

[44] Greenwood et al (1997) argue that current cost depreciation is the correct measure in the presence of embodied technical change.

Table 2B: Financial Development Measures

Country	CRE70s	CRE80	CAP80	FOR80	CRE90	CAP90	FOR90
Australia	0.281	0.4007	0.809	0.9029	0.748	1.4354	1.523
Austria	0.6357	0.7585	0.872	0.9311	0.9301	1.8062	1.8783
Bangladesh	0.0561	0.1637	0.1726	0.1906	0.1987	0.226	0.2369
Belgium	0.2481	0.2952	0.5288	0.7282	0.7232	1.0667	1.2886
Brazil	0.5322	0.5594	0.6179	0.8002	0.5681	0.8029	0.9058
Canada	0.4709	0.6891	1.1962	1.2605	0.7819	1.499	1.6038
SriLanka	0.1556	0.2002	0.2737	0.3601	0.206	0.3466	0.3947
Chile	0.1724	0.6117	0.8495	1.2247	0.5729	1.4936	1.7319
Colombia	0.1236	0.1368	0.1855	0.3801	0.2045	0.3594	0.5304
Costa	0.2314	0.1711	0.1986	0.3472	0.1821	0.2815	0.4804
Denmark	0.4974	0.5051	0.712	0.9418	0.4692	0.9225	1.1188
Finland	0.4575	0.7366	0.8712	0.9629	0.7599	1.2354	1.3868
France	0.4813	0.7893	0.9464	0.9856	0.8656	1.2046	1.2761
Germany	0.7788	0.9356	1.1198	1.208	1.0132	1.2875	1.4444
Greece	0.3177	0.397	0.4589	0.6561	0.3762	0.7944	1.0722
India	0.1725	0.2825	0.346	0.3701	0.2633	0.5747	0.6151
Israel	0.4458	0.6279	0.9829	1.1243	0.7823	1.2384	1.3577
Italy	0.6931	0.5233	0.6447	0.7023	0.5899	0.79	0.9191
Japan	1.2664	1.6361	2.4757	2.4983	1.9469	2.7464	2.8179
Jordan	0.3096	0.581	1.0645	1.5474	0.6645	1.3394	1.9825
Kenya	0.1304	0.1698	0.2111	0.6287	0.2293	0.3473	0.6916
Korea	0.4391	0.5721	0.834	0.9182	0.7398	1.1994	1.2411
Malaysia	0.3375	0.7965	1.4687	1.6501	1.2702	3.1125	3.2147
Mexico	0.2783	0.2256	0.2883	0.66	0.2804	0.6192	0.8059
Morocco	0.1613	0.1837	0.2261	0.4927	0.3777	0.584	0.8
Netherlands	0.5444	0.6844	1.0278	1.203	0.9242	1.6335	2.0477
New Zealand	0.1756	0.4055	0.9026	1.1696	0.9586	1.3857	1.5425
Norway	0.3299	0.4864	0.5935	0.7237	0.6086	0.9084	1.0203
Pakistan	0.2319	0.2532	0.3056	0.3756	0.2414	0.3955	0.4942
Peru	0.1044	0.0835	0.1211	0.317	0.162	0.2996	0.4292
Philippines	0.2373	0.2291	0.3233	0.4667	0.3727	0.8892	1.015
Portugal	0.8579	0.7385	0.8205	1.1724	0.7294	0.9337	1.1415
Singapore	0.5832	0.9843	2.2515	2.4773	1.1152	2.9326	3.1963
South Africa	0.4958	0.5503	1.7223	1.8476	0.7134	2.3868	2.4777
Zimbabwe	0.3237	0.2308	0.3223	0.441	0.2031	0.4599	0.5957
Spain	0.7858	0.7565	0.9129	0.9921	0.7872	1.1346	1.24
Sweden	0.4308	0.448	0.7905	0.8749	0.4098	1.2402	1.3938
Turkey	0.1686	0.176	0.1798	-	0.2061	0.2305	-
Egypt	0.1573	0.2669	0.2928	0.3948	0.3565	0.5443	0.6817
UK	0.3196	0.7331	1.3825	1.4526	1.216	2.5667	2.7581
Venezuela	0.2655	0.2609	0.3027	0.8569	0.1292	0.2478	0.6689

Table 3: Correlations Across Decades

This table shows the autocorrelations across decades (the 1970s, 1980s and 1990s) for each of the technological measures - Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB) , Human capital (HC) - and of external finance dependence (EFD). Standard errors are reported in parentheses. In this table, and the tables that follow, one, two and three asterisks indicate significance at the 10%, 5% and 1% levels, respectively.

	80s - 90s	*70s - 80s*	*70s - 90s*
EFD	**0.89***** (0.088)	**0.48***** (0.172)	0.32* (0.186)
FIX	**0.96***** (0.054)	**0.97***** (0.049)	**0.96***** (0.058)
DEP	**0.96***** (0.057)	**0.98***** (0.035)	**0.95***** (0.064)
ETC	**0.63***** (0.152)	**0.74***** (0.131)	**0.62***** (0.154)
RND	**0.92***** (0.078)	**0.91***** (0.080)	**0.77***** (0.124)
LMP	**0.82***** (0.113)	**0.63***** (0.153)	**0.50***** (0.169)
LAB	**0.97***** (0.047)	**0.97***** (0.051)	**0.93***** (0.070)
HC	**0.98***** (0.036)	**0.96***** (0.058)	**0.90***** (0.084)

Table 4: Correlations Among Technological Measures

This table shows cross-correlations among the technological measures - Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB), Human capital (HC), computed for three time periods: the 1970s, 1980s and 1990s. Standard errors are reported in parentheses. In this table, and the tables that follow, one, two and three asterisks indicate significance at the 10%, 5% and 1% levels respectively.

1970s

	FIX	DEP	LMP	ETC	RND	LAB
DEP	-0.23 (0.191)	1.00				
LMP	**-0.58***** (0.160)	**0.36*** (0.183)	1.00			
ETC	0.03 (0.196)	-0.20 (0.192)	0.09 (0.195)	1.00		
RND	**-0.39**** (0.180)	0.30 (0.187)	**0.53***** (0.166)	0.29 (0.187)	1.00	
LAB	**-.33*** (0.185)	**0.41**** (0.179)	0.15 (0.194)	-0.18 (0.193)	-0.07 (0.193)	1.00
HC	**0.53***** (0.166)	-0.11 (0.195)	-0.09 (0.195)	0.11 (0.195)	0.25 (0.195)	**-0.48***** (0.172)

1980s

	FIX	DEP	LMP	ETC	RND	LAB
DEP	-0.12 (0.195)	1.00				
LMP	**-0.61***** (0.156)	**0.39**** (0.180)	1.00			
ETC	-0.07 (0.196)	0.18 (0.193)	**0.39**** (0.181)	1.00		
RND	**-0.44**** (0.176)	0.13 (0.194)	**0.68***** (0.144)	0.31 (0.187)	1.00	
LAB	-0.19 (0.156)	**0.40**** (0.180)	0.23 (0.191)	0.14 (0.194)	-0.17 (0.193)	1.00
HC	**0.47**** (0.173)	-0.15 (0.194)	-0.17 (0.193)	-0.01 (0.196)	0.27 (0.189)	**-0.52***** (0.167)

Table 4 (-continued-): Correlations Among Technological Measures

1990s

	FIX	DEP	LMP	ETC	RND	LAB
DEP	-0.17 (0.193)	1.00				
LMP	**-0.73***** (0.134)	0.27 (0.189)	1.00			
ETC	**0.35*** (0.184)	0.05 (0.196)	**0.36*** (0.183)	1.00		
RND	**-0.40**** (0.179)	0.07 (0.196)	**0.54***** (0.165)	**0.46***** (0.174)	1.00	
LAB	-0.12 (0.195)	**0.31*** (0.186)	0.30 (0.187)	-0.28 (0.188)	-0.18 (0.193)	1.00
HC	**0.38**** (0.181)	-0.11 (0.195)	**-0.38**** (0.181)	0.08 (0.196)	0.24 (0.191)	**-0.64***** (0.151)

Table 5: Correlations of Technological Measures with EFD

This table shows correlations between industry rankings based on different technological measures - Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB) , Human capital (HC) - and external finance dependence (EFD), computed for three time periods: the 1970s, 1980s and 1990s. Standard errors are reported in parentheses. In this table, and the tables that follow, one, two and three asterisks indicate significance at the 10%, 5% and 1% levels respectively.

	EFD		
	1970s	***1980s***	***1990s***
FIX	0.22 (0.191)	-0.14 (0.194)	-0.25 (0.190)
DEP	0.04 (0.196)	0.13 (0.194)	0.06 (0.196)
LMP	**0.32*** (0.186)	**0.59***** (0.159)	**0.47**** (0.173)
ETC	0.09 (0.195)	0.25 (0.190)	0.30 (0.187)
RND	0.28 (0.189)	**0.80***** (0.117)	**0.85***** (0.102)
LAB	-0.01 (0.196)	0.00 (0.196)	-0.09 (0.195)
HC	0.31 (0.187)	0.23 (0.191)	0.15 (0.194)

Table 6: Cross-country Industry Growth Regressions with CRE as a Measure of Financial Development

This table presents the results of the panel regression estimation of equation (5), with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or of technological measure X with financial development (denoted $\hat{X}$). The technological measures are Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB), Human capital (HC). Only regression coefficients and standard errors for $\hat{X}$'s are reported. Each cell represents a regression. In this table, the financial development indicator is CRE = Private Credit/GDP and the sample period covers the 1970s, the 1980s and the 1990s. Results are corrected for heteroskedasticity using the Huber-White procedure. Standard errors are reported in parentheses. One, two and three asterisks indicate significance at the 10%, 5% and 1% levels respectively.

The number of observations is 1034 in the 1970s, 1084 in the 1980s and 968 in the 1990s.

Interaction Variables $\hat{X}$	**Regression Specification**					
	CRE/1970s		*CRE/1980s*		*CRE/1990s*	
	Coefficients	R^2	Coefficients	R^2	Coefficients	R^2
$\widehat{EFD}$	**0.030*** (0.018)	0.42	**0.033**** (0.021)	0.38	0.022 (0.017)	0.30
$\widehat{FIX}$	**-0.031*** (0.018)	0.42	-0.009 (0.032)	0.38	-0.242 (0.019)	0.30
$\widehat{DEP}$	0.024 (0.018)	0.42	**0.036*** (0.028)	0.38	0.033 (0.023)	0.30
$\widehat{LMP}$	**0.054***** (0.020)	0.42	**0.037**** (0.024)	0.38	0.028 (0.020)	0.30
$\widehat{ETC}$	-0.009 (0.013)	0.42	0.014 (0.022)	0.38	0.005 (0.017)	0.30
$\widehat{RND}$	**0.035*** (0.020)	0.42	**0.049***** (0.023)	0.39	**0.038**** (0.018)	0.30
$\widehat{LAB}$	0.027 (0.017)	0.42	-0.015 (0.028)	0.38	0.029 (0.023)	0.30
$\widehat{HC}$	0.001 (0.016)	0.42	**0.055**** (0.036)	0.39	0.005 (0.018)	0.30

Table 7: The "Horse Race" between $\widehat{\text{EFD}}$, $\widehat{\text{LMP}}$ and $\widehat{\text{RND}}$

This table presents the results of the panel regression with industry shares, industry and country fixed effects, and the interaction term(s) of EFD and RND with financial development (denoted $\hat{X}$). In this case, a column represents a regression. Only regression coefficients and standard errors for $\hat{X}$'s are reported. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{X}$	**Regression Specification**					
	CRE/1970s		*CRE/1980s*		*CRE/1990s*	
	Coefficients	R^2	Coefficients	R^2	Coefficients	R^2
$\widehat{\text{EFD}}$, young	0.014 (0.016)	0.42	-0.024 (0.026)	0.38	-0.045 (0.040)	0.30
$\widehat{\text{RND}}$, young	0.008 (0.022)		**0.065**** (0.031)		**0.072*** (0.040)	
$\widehat{\text{LMP}}$, young	**0.045**** (0.023)		0.005 (0.024)		0.010 (0.022)	

Table 8: Cross-country Industry Growth Regressions with CAP as a Measure of Financial Development

This table presents the results of the panel regression estimation of equation (5), with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or of technological measure X with financial development (denoted $\hat{X}$). The technological measures are Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB), Human capital (HC).. Only regression coefficients and standard errors for $\hat{X}$'s are reported. Each cell represents a regression. In this table, the financial development indicator is CAP = (Domestic Private Credit + Domestic Market Capitalization)/GDP and the sample period is the 1980s and the 1990s. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{X}$	**Regression Specification**			
	CAP/1980s		*CAP/1990s*	
	Coefficients	R^2	Coefficients	R^2
$\widehat{EFD}$	**0.038**** (0.015)	0.39	0.014 (0.016)	0.30
$\widehat{FIX}$	-0.004 (0.022)	0.38	-0.020 (0.019)	0.30
$\widehat{DEP}$	**0.037*** (0.019)	0.39	0.036 (0.022)	0.30
$\widehat{LMP}$	**0.039**** (0.017)	0.39	0.021 (0.019)	0.30
$\widehat{ETC}$	0.020 (0.015)	0.38	-0.006 (0.017)	0.30
$\widehat{RND}$	**0.048***** (0.017)	0.39	**0.032*** (0.017)	0.30
$\widehat{LAB}$	-0.009 (0.020)	0.38	0.033 (0.021)	0.30
$\widehat{HC}$	**0.055**** (0.025)	0.39	0.009 (0.018)	0.30

Table 9: Cross-country Industry Growth Regressions with FOR as a Measure of Financial Development

This table presents the results of the panel regression estimation of equations (5), with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or of technological measure X with financial development (denoted $\hat{X}$). The technological measures are Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB), Human capital (HC). Only regression coefficients and standard errors for $\hat{X}$'s are reported. Each cell represents a regression. In this table, the financial development indicator is FOR = CAP+Foreign liabilities/GDP and the sample period is the 1980s and the 1990s. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{X}$	**Regression Specification**			
	FOR/1980s		*FOR/1990s*	
	Coefficients	R^2	Coefficients	R^2
$\widehat{EFD}$	**0.044***** (0.016)	0.38	0.017 (0.020)	0.30
$\widehat{FIX}$	-0.006 (0.023)	0.37	-0.028 (0.024)	0.30
$\widehat{DEP}$	**0.034*** (0.021)	0.37	0.045 (0.029)	0.30
$\widehat{LMP}$	**0.041**** (0.018)	0.38	0.022 (0.025)	0.30
$\widehat{ETC}$	0.024 (0.016)	0.37	-0.006 (0.022)	0.30
$\widehat{RND}$	**0.055***** (0.017)	0.38	**0.036*** (0.021)	0.30
$\widehat{LAB}$	-0.011 (0.021)	0.37	0.036 (0.026)	0.30
$\widehat{HC}$	**0.057**** (0.026)	0.38	0.008 (0.023)	0.30

Table 10: Cross-country Industry Growth Regressions with Lagged Financial Development Measure

This table presents the results of the panel regression with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or RND – all measured in the 1980s – with financial development CRE measured during the 1970s. The technological measures are Fixed capital (FIX), Depreciation (DEP), Obsolescence (ETC), R&D (RND), Investment lumpiness (LMP), Labor intensity (LAB), Human capital (HC). Only regression coefficients and standard errors for $\hat{X}$'s are reported. Each cell represents a regression. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{X}$	Regression Specification	
	CRE/1970s,	
	Coefficients	R^2
$\widehat{EFD}$	0.015 (0.015)	0.36
$\widehat{FIX}$	-0.021 (0.022)	0.36
$\widehat{DEP}$	0.031 (0.021)	0.37
$\widehat{LMP}$	**0.035**** (0.017)	0.37
$\widehat{ETC}$	0.001 (0.014)	0.36
$\widehat{RND}$	**0.039**** (0.017)	0.37
$\widehat{LAB}$	-0.016 (0.021)	0.36
$\widehat{HC}$	0.035 (0.026)	0.37

Table 11: Cross-country Industry Growth Regression with Instrumental Variables

This table presents the results of the panel regression with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or RND with financial development measure CRE during the 1980s, where CRE is instrumented using legal origin as suggested by La Porta et al (1998) or with CRE measured during the 1970s (instrumented interactions are denoted $\hat{\hat{X}}$). Only regression coefficients and standard errors for $\hat{\hat{X}}$'s are reported. Each cell represents a regression. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{\hat{X}}$	**Regression specification**			
	Instrumental Variable: Legal Origin		*Instrumental Variable: CRE/1970s*	
	Coefficients	R^2	Coefficients	R^2
$\widehat{\widehat{EFD}}$	**0.048**** (0.024)	0.38	0.017 (0.018)	0.38
$\widehat{\widehat{LMP}}$	**0.062**** (0.028)	0.39	**0.041**** (0.020)	0.39
$\widehat{\widehat{RND}}$	**0.048**** (0.024)	0.39	**0.045**** (0.019)	0.39

Table 12: Correlations between RND, EFD, LMP for Young and Mature Firms.

This table shows cross-correlations for each variable between its value as measured for young and mature firms. Results are reported for each decade separately.

	1970s	***1980s***	***1990s***
EFD	**0.79***** (0.120)	0.13 (0.195)	**0.80***** (0.119)
RND	**0.80***** (0.117)	**0.83***** (0.109)	**0.93***** (0.072)
LMP	**0.57***** (0.137)	**0.67***** (0.146)	**0.79****** (0.120)

Table 12 (cont): Correlations between RND, EFD, LMP for Young and Mature Firms.

This table shows cross-correlations among RND, LMP and EFD as measured for young and mature firms. Results are reported for each decade separately.

	1970s Young	1970s Mature	1980s Young	1980s Mature	1990s Young	1990s Mature
EFD/RND	.23 (.191)	**.39**** (.180)	**.50***** (.170)	-.14 (.196)	**.41**** (.179)	.26 (.189)
EFD/LMP	**.33*** (.185)	**.36***** (.064)	**.58***** (.160)	**.38**** (.181)	**.37*** (.182)	.13 (.195)
RND/LMP	**.56***** (.139)	**.39***** (.164)	**.77***** (.125)	**.54***** (.165)	**.54***** (.165)	**.58***** (.160)

Table 13: Cross-country Industry Growth Regressions for Different Age Groups/1980s

This table presents the results of the panel regression with industry shares, industry and country fixed effects, and the interaction term(s) of EFD or RND with financial development (denoted $\hat{X}$). EFD and RND are measured using young firms only, or mature firms only. Only regression coefficients and standard errors for $\hat{X}$'s are reported. Each cell represents a regression. Results are corrected for heteroskedasticity using the Huber-White procedure.

Interaction Variables $\hat{X}$	**Regression specification**					
	CRE/1970s		*CRE/1980s*		*CRE/1990s*	
	Coefficients	R^2	Coefficients	R^2	Coefficients	R^2
$\widehat{EFD}$, young	0.021 (0.017)	0.42	0.029 (0.019)	0.38	0.009 (0.026)	0.30
$\widehat{RND}$, young	**0.034*** (0.020)	0.42	**0.042***** (0.016)	0.39	**0.033*** (0.017)	0.30
$\widehat{LMP}$, young	**0.059***** (0.018)	0.42	**0.045***** (0.16)	0.39	**0.032*** (0.019)	0.30
$\widehat{EFD}$, mature	**0.033*** (0.018)	0.42	-0.001 (0.012)	0.38	0.011 (0.024)	0.30
$\widehat{RND}$, mature	**0.043***** (0.017)	0.42	**0.055***** (0.018)	0.39	**0.047***** (0.018)	0.30
$\widehat{LMP}$, mature	**0.040**** (0.019)	0.43	**0.046***** (0.018)	0.39	**0.043**** (0.020)	0.30

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